United Solar Systems Corporation and Energy Conversion Devices

R&D and Technology Partners

US DOE NREL THIN FILM PV PARTNERSHIP

Background

Energy Conversion Devices, Inc. (ECD), and its joint venture, United Solar Systems Corporation (United Solar), both in Troy, Michigan, have been involved in research and development (R&D), manufacturing, and sales of amorphous silicon (a-Si)-alloy photovoltaic (PV) products and systems for more than a decade. To reduce manufacturing cost, ECD has pioneered the deposition of a-Si-alloy solar cells on long rolls of thin stainless steel using a continuous roll-to-roll process. To improve sunlight-to-electricity conversion efficiency, ECD and United Solar are aggressively pursuing R&D in the area of material development and cell design. United Solar holds the world record for the highest stabilized efficiency of an a-Si PV module at greater than 10% for a multijunction amorphous 0.09-m^2 silicon-alloy module. This is a milestone for thin-film PV, and strongly supports its potential for the commercial reality of low-cost production. The research that led to this world record performance was done under a cost-shared cooperative project between industry and the U.S. Department of Energy/National Renewable Energy Laboratory (DOE/NREL) within the Thin-Film Partnership Program, which is designed to ensure sustained U.S. leadership in thin-film PV technology.

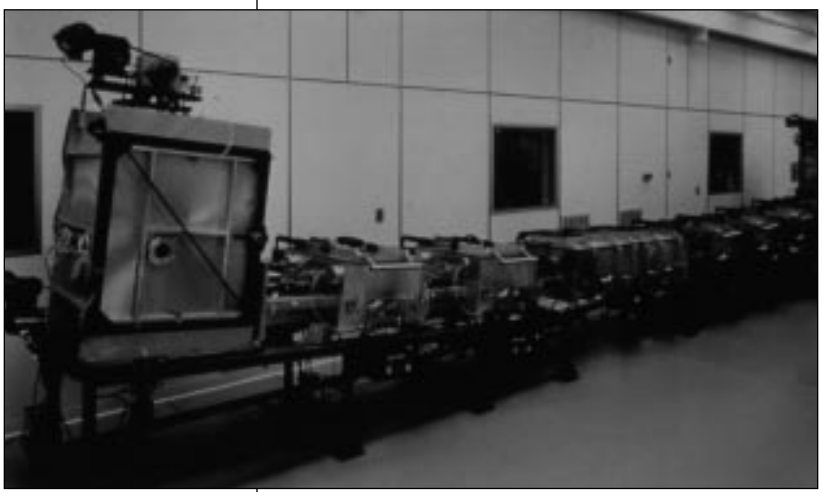

Figure 1. United Solar's roll-to-roll a-Si-alloy deposition equipment.

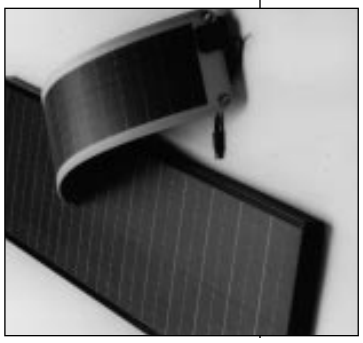

Figure 2. United Solar products.

In 1978, DOE began a research program on a-Si materials and devices as a part of its Photovoltaic Advanced Research and Development program. In FY 1983, the Solar Energy Research Institute (SERI) began a government/industry cost-shared, 3-year (FY 1984–FY 1986) integrated research program to accelerate the advancement of a-Si module technology by U.S. companies. A second government/industry cost-shared program subcontracted by SERI was started in FY 1987 and was conducted from FY 1987–FY 1989. The emphasis of this research was on multijunction a-Si technology and improved performance. ECD was one of four organizations funded under the second cost-shared program, receiving $4.05 million (with ECD cost sharing another $4.52 million) over a 3-year period. A third cost-shared program was started in 1990, and another 3-year award was made to United Solar in the amount of $3.1 million (cost shared by the same amount).

Under a team arrangement in 1994, United Solar and ECD received $1,260,000 and $945,000 (50% and 70% cost shared by the companies, respectively). Subsequently, early in 1995, a 3-year contract was awarded to United Solar in the amount of $1,993,000 (cost shared in the same amount) under the Thin-Film Partnership Program. United Solar has a small manufacturing plant in Troy, Michigan (Figure 1), with an annual capacity of 2 megawatts (MW). The flexible and rugged products (Figure 2) on stainless steel substrates are used for a variety of power applications, both ground-mounted (Figure 3) and rooftop (Figure 4).

In 1996–1997, United Solar built a 5-MW_p a-Si-alloy PV manufacturing plant in Troy, Michigan. The plant is now operational. This is the first large-scale thin-film PV plant in the world. The purpose of the Partnership Program is to support this kind of transition to the marketplace while providing a basis for improvements in PV device designs for future efficiency increases.

Technical Highlights

PV, the direct conversion of sunlight into electricity, is one of the most environmentally safe renewable energy options for the world. United Solar/ECD's a-Si modules have been designed to capture different parts of the solar spectrum to increase their sunlight-to-electricity conversion efficiency. The best stabilized efficiency, 10.2%, was verified by NREL after the 0.09-m^2 module had been light soaked for 1000 hours. Figure 5 shows the excellent recent progress of a-Si prototype modules over the last decade.

The new work by United Solar under the Thin-Film Partnership Program addresses technical issues of solar cell and module development to consistently reach a high stabilized conversion efficiency. It also covers innovative new processes to lower manufacturing costs. The goal is to

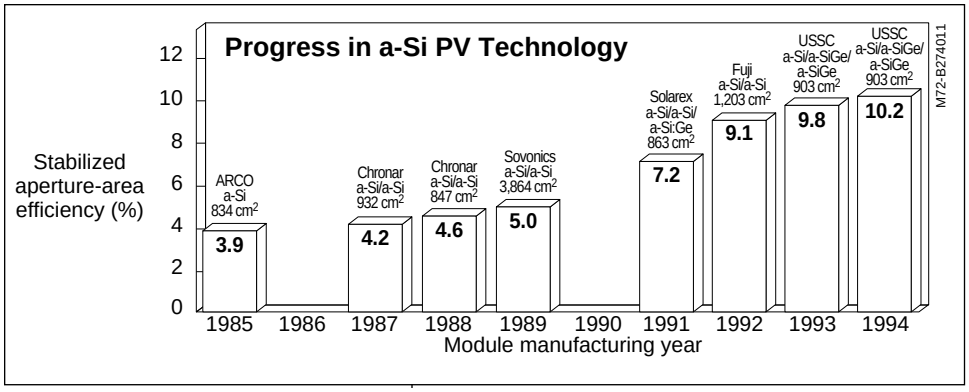

Figure 5. United Solar's 10% a-Si module is twice as efficient as the best a-Si modules of the 1980s.

Figure 3. United Solar's PV ground-mounted system in Newport News, Virginia.

obtain 12% stabilized efficiency PV modules by 1997 that will pass the NREL Qualification Tests. The technology being developed is likely to play a key role in United Solar's future large-volume production of low-cost PV modules.

The partnership work involves (1) back reflector development, (2) methods to improve the intra-module connections, and (3) low-cost encapsulation. The back reflector work is to enhance the light trapping without parasitic optical losses at each reflection interface, to optimize the texturing of the back reflector to maximize the light trapping, and to improve the uniformity of the back reflector deposition for high yield. The intra-module connection development involves the use of a new laser process, which represents an improvement in the present manufacturing process. The new interconnection scheme required an insulating layer (such as silicon nitride) to separate the stainless steel substrate from the back reflector. The insulating layer will also reduce the electrical shunt losses now experienced. The new encapsulation that will replace the EVA/Tefzel is a silicon-carbon-oxygen alloy film. The primary elements for the success of the Partnership program are (1) reliable insulator films, (2) thin-film environmental protection, and (3) small, laser-etched electrical conduits.

Figure 4. United Solar's PV roof system in Kansas City, Missouri.

As a result of Partnership activities, United Solar made significant progress in improving the efficiency of advanced triple-junction a-Si PV cells. This results in a 20% improvement in record cell efficiency. In 1997, United Solar produced a 12.1% record cell verified under standard conditions at NREL.

Future Plans

The research carried out under the Thin-Film Partnership is already leveraging new manufacturing operations. ECD designed and built two new manufacturing lines. The first was a 2-MW plant for its joint venture in Russia. The plant was optimized in the United States. The second was the 5-MW manufacturing plant in Troy. Both plants use a state-of-the-art multijunction approach and bring to fruition many innovations that were developed under the research programs supported by DOE/NREL. Subhendu Guha, vice president of Research and Technology at United Solar, said, "The work carried out under the Thin-Film Partnership Program will lead to further reduction in the manufacturing cost of the products and will help in maintaining the U.S. lead in this advanced technology of great societal and commercial significance."

For additional information, contact:

At NREL:

Tom Surek	(303) 384-6471
Ken Zweibel	(303) 384-6441
Harin Ullal	(303) 384-6486
Howard Branz	(303) 384-6694

At United Solar:

Subhendu Guha	(810) 362-3120

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